**EFFECTS OF STATE ROUTE 23 WIDENING PROJECT AND
ACCOMPANYING MITIGATION MEASURES ON
CULVERT USE AND ROAD MORTALITY OF WILDLIFE**

FINAL REPORT

**NATIONAL PARK SERVICE
SANTA MONICA MOUNTAINS NATIONAL RECREATION AREA**

Prepared for:

Caltrans District 7
Division of Environmental Planning
(Mail Stop 16A)
100 South Main Street
Los Angeles, CA 90012
Contact: Michael Klima
(213) 897- 2597

Prepared by:

Jeff Sikich- National Park Service
Santa Monica Mountains National Recreation Area
401 West Hillcrest Drive
Thousand Oaks, CA 91360
Contact number: (805) 370-2395

Seth Riley- National Park Service
Santa Monica Mountains National Recreation Area
401 West Hillcrest Drive
Thousand Oaks, CA 91360
Contact number: (805) 370-2358

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Executive Summary

This report summarizes a project conducted by the National Park Service in collaboration with the California Department of Transportation (Caltrans) to monitor wildlife movement across State Route 23 (SR 23) in Ventura County, California from January 2004 through August 2011. The objective of this project was to determine the effectiveness of three measures by Caltrans to reduce road impacts on wildlife, particularly medium-sized and large mammals, along SR 23 following a lane expansion. The mitigation efforts included clearing out underpasses that were filled with sediment and likely less usable by wildlife, constructing exclusion fences along both sides of the highway, and installing one-way gates that allow animals inside the fencing to escape. We measured the effectiveness of these efforts by monitoring culvert use and road mortality of wildlife both before and after the highway modifications and construction and by monitoring one-way gate use after they were installed. Our project is one of few that have studied wildlife road mortality and crossing use both before and after the installation of exclusion fencing and improvements to existing wildlife-crossing structures.

Before the construction of two additional lanes along SR 23, we conducted road mortality surveys for 34 months by driving the 3.2 km stretch of the highway in both directions three times a week to document animals killed by vehicle collisions. We used remote digital cameras to simultaneously monitor wildlife use of three culverts along the same stretch of highway, two of which were significantly obstructed by debris. During construction the two blocked culverts were cleared, and an entirely new right-of-way fence, including 12 one-way gates, was built along the highway. Highway mortality and culvert monitoring were performed in the same manner for 27 months post-construction. Remote digital cameras were used to monitor the 12 one-way gates after they were installed, during post-construction monitoring.

Mammals represented the highest percentage of road mortality during both pre-construction (63%) and post-construction (76%) surveys. After mammals, bird species represented 25% of pre-construction and 15% of post-construction roadkills. Reptiles and amphibians may have been underrepresented in our mortality counts, because they were difficult to detect from the vehicle due to their small size. Among mammals, rabbits (*Sylvilagus* spp.) represented the most roadkills both before (21%) and after (51%) the wildlife proof fence was constructed. For coyotes (*Canis latrans*), the largest mammal detected in the study area, road mortalities declined 88%, from 43 to 5, after the fence was built. However, there was no reduction in the frequency of road mortalities for all other detected species. Road mortalities actually increased slightly for medium-sized mammals excluding coyotes from 19 to 21, and for small mammals, after the fence was built, with rabbit roadkills increasing fourfold. The overall rate of road mortalities was 0.47 animals killed/km/week pre-construction and increased to 0.70 animals killed/km/week post-construction. Although the fence reduced road mortalities for coyotes, the lack of change in road mortality for other species suggests that smaller animals were finding ways through or around the fence.

Our monitoring data indicated that the one-way gates were used by both wildlife and humans in both directions. Human use damaged some of the gates allowing animals to pass through the gate the unintended direction more easily. Although we documented use of the gates in the wrong direction by all animal species detected in the study area, two-thirds of the one-way gate

uses were in the intended direction (i.e. away from the highway). We suspect animals could have entered the right-of-way by going around the fence ends or through holes along the fence line, but once inside they seemed to also use the one-way gates the intended way and avoided crossing the road.

The pre-construction culvert monitoring data showed extensive wildlife use of the open culvert, but the two blocked culverts received significantly less use. Wildlife use of the three culverts increased after the wildlife-proof fence was constructed and the two blocked culverts were cleared. Animal detections increased 2- and 3-fold at the two blocked culverts once cleared (from 0.32 to 0.72 detections/day at Culvert A, and from 0.32 to 0.92 detections/day at Culvert C). The culvert that required no modification also showed an increase in wildlife use (from 2.18 to 3.54 detections/day at Culvert B). We also documented confirmed crossings (defined as a picture of the same species, going the same direction, at both ends of the same culvert within 10 minutes) in the two cleared culverts for coyotes, raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), and opossums (*Didelphis virginiana*). For both of these culverts, there were no confirmed crossings by animals before they were cleared. Even the culvert that did not require modification received 6 times more crossings post-construction by coyotes, raccoons, and skunks, likely as a result of animals being funneled to the culvert entrances by the exclusion fencing. The lack of complete crossings by small mammals (rabbits, squirrels, mice) may be because the culverts were unsuitable for these species because of the lack of protective cover. Although we detected bobcats (*Lynx rufus*) at all 3 culverts post-construction, we did not confirm them going through the entire undercrossing. The culverts may be attractive to bobcats for resting, hunting, or even thermoregulation during hot days. Coyotes and skunks accounted for the most animal pictures and confirmed crossings throughout the study.

The goal of the mitigation was to reduce mortality of medium-sized and large mammals. Our results suggest that the mitigation efforts by Caltrans were effective in increasing culvert use for many medium-sized mammals and reducing road mortality of coyotes, the largest of the mammal species detected in our study area. An important consideration in the implementation of exclusion fencing, one-way gates, and culverts is their relevance to a range of species. Culverts that incorporate multiple mitigation design elements will be most effective in encouraging wildlife passage for a variety of species. Since no deer or large carnivores (e.g. mountain lions) were detected in our study area, it would be valuable if mitigation was also effective for smaller animals. We recommend creating smaller scale cover in the two drier culverts that may encourage use by small mammals, reptiles, and species associated with rocky habitats. The one-way gates show potential value for preventing road mortalities, if they can be modified to prevent people from damaging them and animals from going through the wrong way. We also noted several holes along the bottom of the fence line along both sides of the freeway, so we recommend regular inspection of the wildlife proof fence and maintenance to repair any damage to ensure that animals are not exploiting breaks in the fence. Further, we recommend that the culverts be monitored and maintained over time to ensure that they continue to function properly as both a wildlife passage and drainage system. These results have important implications for future efforts to mitigate the impacts of roads and vehicles on the movement and survival of wildlife.

INTRODUCTION

The impacts of highways on wildlife populations are of increasing concern for transportation and natural resource agencies. Roads and vehicles can affect wildlife populations in numerous ways, including through direct loss of habitat, fragmentation of remaining natural areas, disruption of animal movement, and by causing road mortality (Forman et al. 2003). Wildlife-vehicle collisions are also a major safety concern for motorists and can cause property damage, human injuries, and deaths (Conover et al. 1995). The barrier effects of roads on wildlife are considerable (Beier 1993, Forman & Alexander 1998, Riley 2006) and freeways have been shown to restrict gene flow even in wide-ranging species (e.g. Riley et al. 2006).

The effects of roads and freeways can be especially prevalent in urban landscapes such as those in Southern California, including around Los Angeles, the second most populous metropolitan area in the U.S. and the largest in geographical area. Given the negative effects of roads, wildlife may benefit from the use of underpasses along roadways. Previous studies conducted along the 101, 118, and 23 freeways north of Los Angeles documented wildlife use of beneath-highway passages (culverts, tunnels, underpasses) and wildlife mortality caused by vehicle collisions (Riley et al. 2003, Ng et al. 2004, LSA 2004). On all three highways, coyotes (*Canis latrans*) were the most common medium-sized mammal fatality; the greatest number of coyote roadkills occurred where traffic volume was lowest, on State Route 23, and the fewest took place where traffic volume was greatest, along U.S. Highway 101 (Ng 2000). Many types of undercrossings were utilized by a variety of different species, indicating that beneath-highway passages, even when not originally designed for wildlife, can provide important avenues for animals to cross roads and can increase connectivity in fragmented landscapes (Haas 2000, Clevenger et al. 2001*a*, Ng et al. 2004). Underpass variables, including length, width, and height and the presence of suitable habitat on either side of the passage are important predictors of underpass use for some species (Haas 2000, Forman et al. 2003, Ng et al. 2004). Land management agencies around the world have made efforts to mitigate the negative effects of roads on wildlife, with a focus on reducing road mortality (Forman et al. 2003, Ree et al. 2007, Glista et al. 2009). Where roads pass through natural habitat, wildlife can benefit from tall fences or similar barriers to prevent them from crossing the road and possibly funnel them towards undercrossings. Wildlife proof fences or barriers, underpasses, or combinations of these measures (Ward 1982, Foster & Humphrey 1995, Clevenger et al. 2001*b*, Cain et al. 2003, Dockstader & Southall 2003, Gordan & Anderson 2003, Taylor & Goldingay 2003, Dodd et al. 2004, Klar et al. 2009, McCollister & Van Manen 2010) have been found to effectively reduce highway mortality in a number of studies.

The objective of this project was to determine the effectiveness of three measures to reduce road impacts on wildlife by the California Department of Transportation (Caltrans) along State Route 23 (SR 23) following a lane expansion. Specifically, Caltrans added a lane on each side of the freeway, increasing both directions from two lanes to three. The lanes were added on the inside

of the freeway, in the median, so the total width of the roadway did not change, but the unpaved area of the median was significantly reduced. The mitigation efforts included clearing out underpasses under the highway, constructing exclusion fences along both sides of the highway, and installing one-way gates that allow animals inside the fencing to escape. We hypothesized that fencing and clearing out culverts would reduce wildlife-vehicle mortalities and increase culvert use, allowing safe passageways for wildlife under the highway. We measured the effectiveness of these efforts by monitoring culvert use and road mortality of wildlife before the highway modifications and construction and again after construction. One-way gate use was also monitored after construction. This study provides an excellent opportunity to evaluate the efficacy of mitigation efforts by measuring different aspects of wildlife movement and mortality before and after the highway modifications occurred.

STUDY AREA

The study area consisted of a 3.2 km (2.0 miles) section of SR 23 from post-mile (PM) 8.2 at the Olsen Road exit to PM 10.2 at the Tierra Rejada Road exit in Ventura County, California (Figure 1). The study area was approximately 5 km southeast of the City of Moorpark and approximately 8 km north of US Highway 101. Land use within the project area primarily consisted of agricultural areas and low-density residential areas. A network of unpaved roads occurs throughout the study area and is primarily used to support farming operations. On average, annual daily traffic volume (ADT) along SR 23 was 57,000 vehicles per day in 2007 with a posted speed limit of 105 km/hr (65 miles/hr) for its entire length. To reduce congestion, lanes were added to SR23, since it is a major commute route from Simi Valley and Moorpark to areas south.

METHODS

Wildlife Crossing Points and Mitigation Measures

The 3 underpasses (Figure 2) along the study area were drainage culverts that were originally placed there for hydrologic purposes. Culverts B and C were circular corrugated metal pipe culverts and culvert A was a concrete box culvert with two walls inside it running the length of the culvert and dividing it into 3 tunnels. Sediment filled approximately 75% of Culvert A prior to the Widening Project and was later cleared by Caltrans. Plant and sediment material filled approximately 85% of the western side of Culvert C prior to the Widening Project and clearing by Caltrans. Each of Culvert A's 3 tunnels was 83 m long, 3.2 m wide, and 0.6 m high pre-clearing and measured 3.2 m wide and 1.85 m high after being cleared with an openness ratio (ht x width/length, commonly used in relation to wildlife passages; Reed et al. 1975) of 0.07 m, and

remained dry most of the year. Culvert B required no modification and was 140 m long, 3.2 m wide, and 2.8 m high (openness ratio=0.06 m) and remained dry most of the year. Culvert C was 110 m long, 1.45 m wide, and 0.6 m high pre-clearing and measured 1.45 m wide and 1.9 m high (openness ratio= 0.03 m) after being cleared and had (generally shallow) running water throughout the year. Culvert A was the only underpass that had visibility through the entire length of the culvert, allowing an animal to see the other end. Culvert B was the only underpass that had a dirt substrate along its entire length. Culvert A's floor was covered with dirt for half its length and bare concrete the remaining half, and Culvert C had a constant flow of water running through it at an average height of 8 cm. Culvert C was the only culvert that had natural vegetated areas leading up to both entrances.

Caltrans removed the existing right-of-way fence along both sides of SR 23, which was damaged in many locations, and replaced it with a new fence line along the same footprint. The new chain-link wildlife fence was designed to prevent wildlife from entering the road; it had a mesh size of 7 x 8 cm and was buried 0.6 m (2 ft) into the ground with a total height above ground of 1.8 m (6 ft) or 2.4 m (8 ft) depending on the slope (Figure 3). On both sides of the highway, fences were located at least 7 m from the road and as far away as 100 m. The fences ran parallel to the highway and continued above each of the 3 culverts to funnel animals into the culvert opening. During construction, twelve one-way gates (Figure 4) were also installed (6 on each side) along the fence line to allow animals that do get inside the fencing to escape.

One-way gates were designed to allow easy passage from the road to outside areas, but little or no passage from the outside area to the road. Caltrans and the National Park Service (NPS) modified the one-way galvanized steel escape gate design commonly built for deer (Reed et al. 1974) to also apply to medium sized mammals, since no deer were detected in the study area during 3 years of pre-construction monitoring. Specifically, modifications included placing baler tines in the gates closer together at the bottom (bottom 61 cm spaced 8 cm apart; middle 31 cm spaced 10 cm apart; top 31 cm spaced 13 cm apart) and including 5 x 10 cm wire mesh that was secured on the tines nearest the gate ends extending out 31 cm to prevent flexibility that may allow animals to bend the tines and squeeze through (Figure 5). Tines were left open the remaining 5 cm to allow flexing at the point an animal would pass through the gate (Figure 6). The gate profile was lowered to ground level and chain link fence material was installed at the bottom of the gate and buried 0.6 m to prevent animals from digging under it. Gaps between the fence and gate frame were closed to no larger than 4 cm.

Highway Mortality Monitoring

Before highway construction began, we monitored highway mortality from January 7, 2004 to October 30, 2006 (34 months). Caltrans completed the culvert clearing, one-way gate installation, and 90% of the fence construction by March 12, 2009 (the last section of fence was installed on August 12, 2009). NPS began post-construction road mortality surveys on May 4,

2009 and finished them on August 12, 2011 (27 months). We monitored SR 23 from Tierra Rejada to Olsen Road by driving the 3.2 km stretch of the highway in both directions twice (four times total) to thoroughly observe both sides of the road from each direction for animals killed by vehicle collisions. Monitoring occurred after the morning rush hour three times per week, on Monday, Wednesday, and Friday. For each animal found dead on the road, we recorded species, sex, age (adult or juvenile), date, and exact location in UTM coordinates (Universal Transverse Mercator, datum NAD27) using a Global Positioning System (GPS) device. To prevent double counting, we either removed all animal carcasses from the highway or marked them with spray paint. We also collaborated with Caltrans field personnel in the event that they discovered additional wildlife mortalities on this stretch, so that we could record as many of the road mortalities as possible. The road mortality surveys occurred throughout (and beyond) the periods of culvert monitoring, and they were conducted throughout the year to collect data during different periods of wildlife reproduction and dispersal. The surveys were conducted in the same manner pre- and post-construction. We used a chi-square analysis (observed vs. expected) to test whether wildlife vehicle mortalities differed significantly between the pre-construction and post-construction surveys, with the expected condition that mortality rates were the same pre- and post-construction.

Culvert Monitoring

We monitored the use of the 3 culverts by wildlife from November 4, 2004 to October 30, 2006 (24 months) before construction and culvert clearing and then again from May 4, 2009 to August 12, 2011 (27 months) post-construction. We used remotely triggered infrared digital cameras (pre-construction monitoring: Digital CamTrakker; CamTrak South, Inc., 1050 Industrial Drive, Watkinsville, GA 30677, post-construction monitoring: Reconyx PC 90; Reconyx, Inc., 3828 Creekside Lane, Suite 2, Holmen, WI 54636) to monitor culvert use, with cameras secured in steel containers mounted to the culvert walls (Figure 7). One camera was placed at both entrances of each culvert 40 cm off the ground and positioned at an angle to cover the full width of the structure. Cameras were triggered to take a photograph anytime heat and motion interrupted the infrared beam. Photos were captured at 20 second intervals, and the date and time were recorded on each photo. Cameras operated 24 hours a day and were checked at least once a month to change media cards and batteries. Images from the media cards were downloaded to a computer and each photo was examined to identify species, number of individuals, and direction of travel. Images of the same species, going the same direction, at both cameras of the same culvert within 10 minutes were recorded as a "confirmed crossing" through the underpass. We used a chi-square analysis to test whether animal detections and confirmed crossings in the culverts differed significantly between the pre- and post-construction surveys, as with the mortality surveys.

Digital CamTrakker remote cameras were used in the culverts during our pre-construction monitoring. These cameras had a delay of approximately 2 seconds between the time an animal

broke the infrared heat-in-motion detector and the camera took a photo. This delay caused us to miss animals walking by at a fast pace and would result in a blank picture. When a picture was taken with nothing in it, we recorded this event as a "trip" event. All cameras were positioned in the culvert at an angle to minimize the number of recorded trips. All the CamTrakker remote cameras used during the pre-construction monitoring were damaged in some capacity and had to be repaired or replaced before the start of our post-construction monitoring. Remote digital camera technology improved considerably after the start of the pre-construction monitoring; the CamTrakker model we used was no longer available, so we purchased cameras from a different manufacturer (Reconyx, Inc.) for post-construction monitoring. The Reconyx PC 90 remote cameras used in the post-construction monitoring had a delay of < 1 second between an animal triggering the infrared detector and the camera taking a photo. This resulted in obtaining fewer "trip" events, or photos without an animal.

There were occasions during the study where the cameras were not active, specifically when culverts flooded, cameras were damaged, batteries were depleted, or memory cards were full. During the rainy season cameras had to be removed to prevent them from being damaged. When there was a constant rain, all three culverts filled with water above the camera line. Cameras were placed back in the culvert boxes when the water level declined. We measured the rate of culvert use by dividing the number of animal photos and trip events in the culverts by the number of nights the camera was active.

One-way Gate Monitoring

We monitored all 12 one-way gates for 1 year from August 12, 2010 to August 12, 2011 with Reconyx PC90 remotely triggered infrared digital cameras. Monitoring of the six gates on the east side of SR23 began six months prior to this time period, on February 17, 2010, resulting in a total monitoring time of 18 months for the east side gates. The fast camera speed of these cameras allowed us to detect animal behavior at each one-way gate. One camera was placed 1.5 m in front of and to the side of each one-way gate at a height of 45 cm from the ground to record any animal use (Figure 8). Cameras were located along the inside (freeway side) of the fence line, secured in steel containers that were fastened to a wooden stake driven into the ground, and locked with a 2 meter section of steel chain to a fence post. Media cards and batteries were changed at least every 2 months, with more frequent camera visits at sites that needed more maintenance. The only mammals recorded in our analysis were those that could not fit through the mesh size of the chain link fence (e.g. small mammals, such as mice were not monitored). Occasions occurred during the post-construction monitoring when the cameras were not activated because of depleted batteries and full memory cards. We measured one-way gate use by dividing the number of pictures taken of animals going through (in either direction) or walking by the gate by the number of nights the camera was active.

RESULTS

Highway Mortality Monitoring

Pre-construction surveys

We recorded 222 animal mortalities from vehicle collisions during the 34 months of pre-construction monitoring. Mammals represented the highest percentage of road mortality (63%), followed by birds (25%), reptiles (5%), and amphibians (3%); we detected 11 mammal species in total that were killed (Table 1). On average 69.4 animals were killed per km of highway surveyed during 34 months, and 1.5 animals were killed per week along the 3.2 km stretch, for an overall rate of 0.47 animals killed/km/week. Of the mammals, rabbits (47, 21%), and coyotes (43, 19%) accounted for the most road mortalities (Figure 9). Twenty-seven (63%) of the coyotes were hit near Culvert B (Figure 10), which is the culvert where we had the most photo-documented coyote activity. Coyotes were hit every month of the year, and 26 (76%) out of 34 months surveyed had ≥ 1 coyote killed with an overall average of 1.26 coyotes killed/month (Table 2). The rate of road mortalities/day was 0.14 for medium-sized mammals (0.04 excluding coyotes), 0.18 for smaller mammals, 0.13 for birds, and 0.04 for herpetofauna.

Post-construction surveys

We recorded 265 animal mortalities from vehicle collisions during the 27 months of post-construction monitoring after the mitigation measures were completed. Mammals represented the highest percentage of road mortality (76%), followed by birds (15%), and reptiles (5%); we detected 13 mammal species in total that were killed (Table 1). On average 82.8 animals were killed per km of highway surveyed, and 2.2 animals were killed per week for the whole stretch, for an overall rate of 0.70 animals killed/km/week. Of the mammal species, rabbits accounted for the most road mortalities (51%; Figure 11) followed by squirrels (8%). We recorded 5 coyotes, 1 bobcat (*Lynx rufus*), and 1 badger (*Taxidea taxus*) killed by vehicles post-construction. The rate of road mortalities/day was 0.10 for medium-sized mammals (0.08 excluding coyotes), 0.52 for smaller mammals, 0.12 for birds, and 0.04 for herpetofauna.

Road mortality comparison pre- and post-construction

The total number of animal (mammals, birds, reptiles, and amphibians combined) road mortalities was significantly higher during the post-construction surveys than during the pre-construction surveys (χ^2= 20.34, d.f.= 1, P<0.001). The total number of coyotes killed by vehicle collisions was significantly lower during the post-construction surveys than during the pre-construction surveys (χ^2= 22.30, d.f.= 1, P<0.001), but there was no significant difference in the total number of roadkills of all other medium sized mammals (skunk, raccoon, opossum, bobcat, and badger) during the two survey periods (19 total pre-construction vs. 21 post-construction;

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χ^2= 2.36, d.f.= 1, P>0.10). There were significantly more rabbit road mortalities post-construction than pre-construction (χ^2= 67.0, d.f.= 1, P<0.001).

Culvert Monitoring

Pre-construction monitoring

Remote cameras recorded 2509 photos during pre-construction monitoring, including 1432 photos of various species and 1077 "trip" events where nothing was captured in the picture (Table 3). Coyotes (67%) and striped skunks (*Mephitis mephitis*; 17%) accounted for most of the animal pictures. The highest percentage of animal pictures taken were of rabbits (42%) and birds (19%) in Culvert A, of coyotes (74%) in Culvert B, and of raccoons (*Procyon lotor*; 41%) in Culvert C. A variety of animals were detected at the culvert entrances; coyotes, raccoons, skunks, squirrels, and rabbits, were detected at all three culverts, and bobcats and opossums (*Didelphis virginianus*) were detected at two of the three culverts. Culvert B had the highest wildlife use with the cameras taking 2.18 photos/monitoring day, while 0.32 photos/monitoring day were taken in both Culverts A and C (Table 3). Coyotes were detected using culvert B nearly every day with 0.9 coyote photos/monitoring day. Remote cameras recorded 43 (86 photos) confirmed crossings by coyotes and skunks with all of these occurring in Culvert B (Table 4). No confirmed crossings were recorded in Culverts A or C pre-construction.

Post-construction monitoring

After the construction period and the mitigation measures were completed (the wildlife proof fence was built and Culverts A and C were cleared, Figure 12), remote cameras recorded 5820 photos, of which 5110 were animals and 710 were "trip" events (Table 3). Skunks (30%) and coyotes (21%) accounted for most of the animal pictures (Figure 13); other species recorded in all three culverts were bobcat, raccoon, opossum, rabbit, and ground squirrel (Otospermophilus beecheyi). The highest percentage of animal pictures taken were of rabbits (35%) and coyotes (12%) in Culvert A, of skunks (51%) and coyotes (23%) in Culvert B, and of raccoons (33%) and skunks (16%) in Culvert C. Culvert B had the highest wildlife use with cameras taking 3.54 photos/monitoring day, while 0.72 photos/monitoring day were taken in Culvert A and 0.92 photos/monitoring day were taken in Culvert C (Table 3). Coyotes also used Culvert B nearly every day with 0.8 coyote photos/monitoring day. Remote cameras recorded 321 (642 photos) confirmed crossings by coyotes, raccoons, skunks, and opossums (Table 4), with coyotes and raccoons passing through all 3 culverts. Coyotes accounted for most (61%) of these crossings. Mammals were photographed at all times throughout the 24 hour period, however 188 (52%) of the confirmed crossings occurred between the hours of 5am and 9pm (i.e. during the day).

Culvert Monitoring comparison pre and post-construction

Confirmed crossings by coyotes, skunks, and raccoons in Culvert B were significantly higher post-construction than during the pre-construction surveys (χ^2= 142.76, d.f.= 1, P<0.001), and Culverts A and C had confirmed crossings (Culvert A= 10, Culvert C=60) of coyotes, raccoons, opossums, and skunks (only in Culvert C) post-construction and none during the pre-construction monitoring surveys. Each culvert had significantly more animal detections post-construction compared to pre-construction (Culvert A, χ^2= 73.32, d.f.= 1, P<0.001; Culvert B, χ^2= 346.66, d.f.= 1, P<0.001; Culvert C, χ^2= 126.31, d.f.= 1, P<0.001).

One-Way Gate Monitoring

Remote cameras recorded 4748 photos of a variety of animals using or passing by the 12 one-way gates. Most of these pictures (2990 or 63%) were of rabbits going through the gate in either direction. The 6 east side gates had more rabbit detections (1.15 rabbit pictures/day) compared to the 6 west gates (0.10 rabbit pictures/day). Excluding rabbits and people, cameras recorded 1097 passages through the one-way gates by medium sized mammals; 67% of these passages were through the gate the intended way (from inside the fenced freeway to the outside). All animals (excluding rabbits) were detected going through the gate the intended way at a rate of 0.18 animal detections/day. Animals were detected going through the gate the wrong way (entering the freeway side of the fence) at a rate of 0.09 animal detections/day. Remote cameras recorded animals walking by the gate inside the fence at a rate of 0.08 detections/day, and walking by the gate on the outside of the fence at 0.06 detections/day (Table 5). Medium- sized animals were detected more frequently at the western gates (0.59 detections/day) than the eastern gates (0.29 animal detections/day). Medium-sized animals were detected using 11 of the 12 one-way gates in both directions, with coyotes, house cats, and skunks being detected the most frequently. People were recorded 58 times using 6 of the gates, and in most of these cases the metal tines were bent, decreasing effectiveness. The 6 gates used by people showed more animal use than the 6 gates not used by people (Table 6). Five of the 6 gates modified and used by people had photo documentation of animals going through the gate the wrong way. All animals detected using the one-way gates (coyote, bobcat, raccoon, badger, skunk, opossum, domestic dog and domestic cat) demonstrated the ability to go through the gates in both directions, including the gates that were not used and bent by people.

DISCUSSION

Highway Mortality Monitoring

The total number of animals found dead on the road remained high, even after the wildlife proof fence was constructed. Yet, we found that wildlife road mortality was significantly reduced for coyotes, the largest mammal detected in the study area, after the fence was completed. Coyote deaths declined 88% after the fence was built. However, there was no reduction in the frequency

of road mortalities for all other detected species. Medium-sized mammals, excluding coyotes, (bobcat, badger, raccoon, skunk, opossum, and domestic dog and cat) and small mammals (rabbit, squirrel, and rodent) road mortalities stayed the same or actually increased after the fence was built. Rabbit road mortalities increased fourfold, there was no apparent change in the frequency of herpetofauna road mortalities, and bird mortalities decreased slightly. Although the fence reduced road mortalities for coyotes, the lack of change in road mortality for other species suggests that most animals were finding ways through or around the fence. Cameras indicated that the one-way gates were frequently used in both directions by all wildlife detected in the study area, and we suspect that many of the animals found on the freeway side of the fence entered by passing through these gates the wrong way.

Animals face substantial consequences from attempting to cross a highway. Ford and Fahrig (2007) examined published data on mammalian roadkill surveys conducted in North America and found that carnivores had a lower roadkill frequency than herbivores or omnivores. They also found a significant relationship between body size and roadkill frequency, with roadkill frequency increasing with body size up to 1.06kg, and then decreasing as body size increased past this point. Out of the 38 species used in the authors' analyses, herbivores (64%) and specifically different rabbit species (50%) accounted for the most roadkills. Our findings of wildlife road mortality support this finding, as rabbits represented the most mammal roadkills both before (21%) and after (51%) the wildlife proof fence was constructed. The highest non-mammalian mortalities were bird species representing 25% of roadkills pre-construction and 15% post-construction. Such species may have been struck while flying across the road, foraging near the road, or scavenging on other roadkill. In studies addressing multispecies road mortalities, birds are most often listed as killed more frequently than mammals, with reptiles and amphibians appearing even less often as roadkill (Clevenger et al. 2003, Forman et al. 2003). This was not the case in our study, as mammals were killed more often than bird species both pre-construction (63%) and post-construction (76%). Reptiles and amphibians may be underrepresented in our mortality counts because they are frequently removed by scavengers and it is difficult to detect them from the vehicle due to their small size.

Culvert Monitoring

The pre-construction culvert monitoring data showed extensive wildlife use of the open culvert (B), but the two blocked culverts (A and C) received significantly less use. Culvert A was difficult to monitor because it had two walls inside it running the length of the culvert dividing it into 3 tunnels. As a result both cameras had to be placed on the outside of the culvert so that an animal walking through any of the 3 tunnels would intersect the infrared beam when it entered or exited. Camera 1 (West) had to be removed regularly and was activated only 30 days pre-construction because the adjacent agricultural field would flood resulting in deep sediment and a pool of water above the camera line. We believe wildlife activity was low in Culvert A because of the constant muddy sediment at the western end. On three occasions we noted tracks from

coyotes attempting to enter the culvert and sinking up to their chest in mud and then turning around and exiting without going through the culvert. Culvert C was also difficult to monitor before it was cleared. Camera 6 (East) was only activated 124 days because of the constant flow of water flooding occasionally above the camera line; the western entrance was also 85% filled with sediment. For both of these culverts, there were no confirmed crossings by animals before they were cleared. Pictures showed coyotes approaching both of these culverts and bobcats (Figure 14) approaching Culvert C, looking in the culvert and not entering it.

Wildlife use of the three culverts increased after the wildlife proof fence was constructed and the two blocked culverts (A and C) were cleared. Animal detections increased 2-fold at Culvert A and 3-fold at Culvert C. Cameras also recorded confirmed crossings in Culverts A and C of coyotes, raccoons, skunks, and opossums. Coyotes, raccoons, and skunks used Culvert B to cross 6 times more often post-construction. This culvert did not require any modification and wildlife use still increased. This may be explained by more animals being funneled towards the culverts and away from the road by the new fence. Although we had a total of 15 bobcat detections at all three culverts and two badger detections at two of the culverts post-construction, we did not observe these animals going through the entire undercrossing. Most of these detections showed bobcats traveling in and out of the culvert entrance. The culverts seem to not be effective for bobcat crossings, but may be attractive to them for resting, hunting, or even thermoregulation during hot days. We also found 1 bobcat road mortality just above Culvert C. This culvert recorded the highest detection (11 of 15) of individual bobcats approaching the culvert entrance, but not continuing through. Coyotes were shown using Culverts A and B the most, while raccoons were detected using Culvert C most frequently. This is likely attributed to the location of Culverts A and B adjacent to orchards and agricultural crops (which offers habitat value for coyotes); additionally, both culverts remained dry most of the year. Culvert C had a constant flow of shallow water running through it, making it good habitat for raccoons to hunt and travel along. Raccoons were repeatedly photographed foraging (Figure 15) in the pools of water inside Culvert C. This culvert provided a natural drainage system and riparian habitat leading up to both entrances of the culvert. We recognize that confirmed crossings and detections at the culvert entrances and the one-way gates were undoubtedly by some individuals repeatedly using the same culvert or gate.

Culvert A documented the least number of animal detections and use. Culvert A's entrances (east and west side) were located closer to the highway than the other two culverts. In addition to poor wildlife cover and habitat next to this culvert, traffic noise and light disturbance from passing vehicles might have discouraged animals from approaching the culvert. The entrances to Culverts B and C were located lower (below grade) and further away from the highway where traffic noise and light disturbance were notably reduced. Culverts B and C also had vegetative cover around the culvert entrances.

One-Way Gate Monitoring

Our monitoring data indicate that the one-way gates were repeatedly used by both wildlife and humans in both directions. Soon after the gates were installed, farm workers (Figure 16) began to use them and bend the tines to pass through in both directions. In most instances, the tines were not bent back to their original shape after the person passed through the gate. Additionally, human use has broken some of the tines completely off the gate, allowing animals to pass through the gate in both directions more easily. The 6 gates used by people also showed the most use by wildlife, and the highest frequency of animals going through the gate in the wrong direction. However, all animals detected showed the ability to pass through the gates in both directions (Figure 17), even those not used by people. Only one gate did not have evidence of animal passage the wrong way, but that gate also had only four animal detections, which was the fewest of any of the gates. Although the gates were often used the wrong way, they seemed to be effective for some individuals, as cameras detected coyotes (Figure 18) and bobcats approaching the gate from outside the freeway, attempting to pass through, and then turning around and leaving. Some coyotes were even photographed biting on the metal tines, possibly in an attempt to bend them to make passage easier (Figure 19). We suspect that many of the passages were from the same individuals that learned how to pass through the gate the wrong way and would continue to do this at other gates. For example, we identified one individual coyote by its extreme case of hair loss (Figure 20), which is commonly associated with mange, using 3 gates on each side of the freeway in both directions over a period of at least 4 months. This individual was also photographed using Culvert B.

Wildlife proof fencing along roads can result in greater amounts of forage and cover for small mammals on the highway side of the fence. The dense herbaceous cover of roadsides can be attractive to many small mammal species (Downes et al. 1997). An early study along highways in the US found a higher presence and density of small mammal species in the right-of-way habitat than in adjacent habitat (Adams et al. 1983). In our study, rabbits had the highest frequency of gate usage in both directions, and we suspect they accessed the right-of-way to forage. Groot Bruinderink and Hazebroek (1996) found that fenced rights-of-way are attractive to herbivores and predators, because there is more forage for grazing and higher densities of small mammals and carrion. Once wildlife enters the fenced right-of-way, they can become trapped and are more likely to get struck by a vehicle unless they pass through the gate again. Coyotes may have been attracted to the roadside edge habitat for hunting. Eleven of the twelve one-way gates detected coyotes inside the right-of-way. All one-way gates had double the amount of passages through the gate the intended way (0.18 passages/day) than the wrong way (0.08 passages/day). It appeared animals were getting into the right-of-way by other means besides going through the one-way gate the unintended direction. We suspect animals could have entered from going around the fence ends or holes along the fence line, but once inside they seemed to also use the one-way gates the intended way and avoid crossing the road. Ludwig and

Bremicker (1983) reported 69% of all passages through one-way gates by mule deer were in a positive direction (from inside the highway to the outside). We found similar results in our study area, as 67% of all passages by medium-sized mammals through one-way gates were from inside the fenced highway section to the outside.

The addition of a lane in both directions along SR23 and the reduction in size of the median could affect wildlife mortality rates. Studies have found that mid-sized and large mammals are particularly vulnerable to vehicle collisions along two-lane, high-speed roads, and birds and small mammals on wider, high-speed highways (Forman and Alexander 1998). Even though coyotes were found inside the right-of-way, few deaths were recorded on the road during our post-construction monitoring. In addition to the exclusion fencing and culvert clearing, an added lane (from two to three) on both sides of the median strip could have made crossing attempts less attractive to coyotes. Likewise, rabbits and other small mammals had a greater distance to travel to reach the safety of the median strip and were more likely to get hit on the road.

The one-way gate cameras provided information on what animals were present in the study area, including rare or more secretive carnivores, such as long-tailed weasels (*Mustela frenata*), bobcats, and badgers (Figure 21). Rabbits (63%) were the most common animal detected near the gates followed by coyotes (13%) and skunks (12%). All species identified near the one-way gates have also been detected in the culverts. Bobcats, badgers, and weasels were detected twice as often near the gates than in the culverts, and rabbits were detected 5 times more often near the gates than in the culverts. Coyotes were detected twice as often in the culverts as at the gates, and skunks were detected 3 times more often in the culverts than near the gates. This suggests that coyotes and skunks used the culverts more than the gates, but rabbits, bobcats, badgers, and weasels used the gates and surrounding habitat more often than the culverts.

We had some knowledge of wildlife movement along SR 23 before our study began. In the local hills south of the study area, NPS studied bobcats and coyotes with radio-collars from 1996-2003. Some individuals moved north and used the area between Olsen and Tierra Rejada Roads adjacent to SR 23. NPS studied 1 radio-collared bobcat and 4 radio-collared coyotes that used the immediate area on both sides of SR 23, demonstrating that these individuals were successfully crossing the highway (Figure 22). The one bobcat we followed mostly used the area west of the highway near Culverts B and C, but we located him once (1 of 42 locations in the study area) just east of the highway north of Culvert A, indicating he made at least two successful crossings. We followed 1 coyote for a month east of SR 23 near Culvert C; he did not cross the highway to our knowledge but was later hit and killed on Olsen Road by a vehicle. Following these individuals with radio-collars provided important information about how these animals were moving along this fragmented landscape. Although we located animals on both sides of the highway, we were uncertain of how they crossed SR 23.

CONCLUSIONS AND RECOMMENDATIONS

Our results suggest that the mitigation efforts by Caltrans were effective in increasing culvert use for many medium-sized mammals and reducing road mortality of coyotes, the largest of the mammal species detected in our study area. Clearing the two heavily silted culverts proved to be a particularly valuable mitigation, as these culverts received significantly more use once cleared. Even the culvert that did not require modification received more wildlife use, likely as a result of animals being funneled to the culvert entrances by the exclusion fencing. Our findings indicate that, for some mammalian carnivores, the culverts appear to be important for maintaining habitat connectivity across a busy highway. The lack of complete crossings by small mammals (rabbit, squirrel, mice) may be because the culverts were too formidable for these prey species, perhaps creating a preference for crossing on the road. The one-way gates show potential value if they can be modified to prevent people from damaging them and animals from going through the wrong way. Although our results measuring culvert use and road mortality before and after the highway modifications are compelling, it is important to recognize that we were not able to monitor presence of activity of wildlife in adjacent habitat during this study (we attempted to, but all adjacent land was private , and we were not granted access). However, we believe the coyote population has not changed significantly between our pre and post-construction monitoring. NPS (in a separate study) has been doing scat transects for coyotes during the course of the SR23 project in lands surrounding the study area in Los Angeles and Ventura counties and has not detected significant changes in coyote numbers.

The majority of published studies involving exclusion fencing and one-way gates along highways show the benefits for ungulates and large carnivores. To our knowledge, few studies have determined the effectiveness of one-way gates for small and medium-sized animals. Since no deer and large carnivores were detected in our study area, it would be valuable if mitigation was also effective for smaller animals as well. An important consideration in the implementation of exclusion fencing, one-way gates, and culverts is their relevance to a range of species. Based on our 5 years of pre- and post-construction monitoring data, the following recommendations have been developed:

A. The wildlife proof fence requires regular inspection and repair to ensure that animals are not exploiting breaks in the fence. Fence maintenance is usually neglected after construction, yet it is important to conduct even with budgets and priorities of transportation agencies changing over time (Forman et al. 2003). Fences are not permanent structures and can fail from improper construction, soil erosion, vandalism, falling trees, vehicular accidents, and animals digging holes under the fence. We have already documented locations along the fence line where water has eroded soil creating gaps under the fence (Figure 23). Caltrans walked the entire fence line in March 2012 and identified 15 of these locations (Figure 24) where animals can fit under the fence and access the right-of-way. The entire fence line should be walked every 6 months to identify and repair any holes and breaks.

Caltrans should consider moving the wildlife proof fence as close to the road as possible in future highway mitigation projects. This will reduce the amount of roadside vegetation and cover along the highway side of the fence and may help reduce the attractiveness of roadsides to a variety of species. Leaving less room between the fence and road may reduce wildlife vehicle collisions.

B. Consider improving the one-way gate design to be more effective in keeping animals and people from entering the right-of-way through it. Our modified one-way gate design resulted in animals passing through the gate the intended way two-thirds of the time. However, we believe the design can be improved by extending the 5 x 10 cm wire mesh out to the end of the tines (Figure 25). A gap of 5 cm between the tine ends should still be kept in place. This should prevent animals from passing through the gate the wrong way between the tines (Figure 26), and should strengthen the tines and prevent them from bending and breaking off (Figure 27). Even with the wire mesh extended to the tine ends, there should still be enough flexing to allow animals to push through. All wildlife species showed the ability to pass through the small gap between the tine ends and flex the gate open (Figure 28). If the tines appear not to flex enough after extending the wire mesh to the tine ends, then a thinner gauge wire mesh could be used. Testing and monitoring of the updated gate design would be required to evaluate its effectiveness. Some of the gates, especially the ones used by people, need repair by replacing bent tines and adding tines that have been broken off. Spring-loaded swing gates (Clevenger and Huijser 2010) should also be added in the fence next to the one-way gates to allow passage for people and prevent them from going through the one-way gates. This should help reduce human damage to the one-way gates and tines. To keep costs down, the spring-loaded gates (Figure 29) can be placed at the 6 gates (3 on each side of freeway) that showed use by people (Gates 1W, 2W, 4E, 4W, 5E, 6E). Gates 4E and 5E showed the most use (76%) by people. Signs in English and Spanish should be placed at each gate directing them to use the spring-loaded swing gate and not the wildlife one-way gate. All one-way and spring-loaded swing-gates should be checked every 6 months to ensure they are functioning properly and identify and repair any broken parts.

Caltrans should consider earthen escape ramps (or jump-outs) to allow wildlife, especially deer, to safely exit the right-of-way in place of one-way gates in future highway mitigation projects (Forman et al. 2003). Earthen escape ramps are an alternative to one-way steel gates and have been shown to be 6 to 12 times more effective than gates in allowing deer to escape the right-of-way (Bissonette and Hammer 2000). Earthen escape ramps are mounds of dirt placed against a backing material constructed on the right-of-way side of the fence that allow animals to jump down to the non-highway side of the fence (Figure 30). The outside walls of the escape ramp must be high enough to discourage animals from jumping onto the ramp and entering the right-of-way. To prevent injury to the jumping animal, the landing spot should consist of loose soil and be free of vegetation. Deer and elk have been found to be the most common users, but bighorn sheep, bears, moose, and cougars have been documented to use the ramps as well

(Clevenger and Huijser 2010). Escape structures need to be carefully planned in future mitigation projects for the wildlife they are targeting. For small-sized mammals such as badgers, small hinged doors at ground level (Figure 31) can allow safe escape of the right-of-way (Clevenger and Huijser 2010).

C. Culverts should be monitored and maintained over time to ensure that they continue to function properly as both a wildlife passage and drainage system. There is a continent-wide trend of neglect of scheduled maintenance of passage structures (Cramer and Bissonette 2005). Culverts need to be continually maintained in order to ensure their continued use by wildlife. Once a year after the rainy season, all 3 culverts should be checked to remove any silt or debris that has accumulated and ensure that water is draining properly. Our results clearly show that wildlife prefer culverts that are not heavily silted in with debris.

D. Add continuous cover throughout Culverts A and B to ensure their use by smaller mammal species. We did not record any complete crossings by small mammals, indicating that the culverts are not effective for passage by these species. Smaller sized mammals, particularly prey species, tend to use passages of a size that allow for their movement, but restricts the movement of their larger predators. In the drier culverts, the cover requirements of smaller mammals may be met by placing pipes or tubes of varying diameter (Figure 32) in the culverts along one side that span the entire length. Cover within the culvert can also be in the form of logs, rock piles, and bushes (Cavallaro et al. 2005, Cramer and Bissonette 2005, Clevenger and Huijser 2010). Modifications creating smaller scale cover in Culverts A and B may encourage use by small mammals, reptiles, and species associated with rocky habitats. Mitigation measures that accommodate the needs of small-sized mammal species will require further monitoring to determine effectiveness. A culvert that incorporates multiple mitigation design elements will be most effective in encouraging wildlife passage for a variety of species.

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Tables and Figures

Table 1. Number of road mortalities along SR 23 survey route, January 7, 2004-October 30, 2006 (pre-construction phase/ 432 survey days) and May 4, 2009-August 12, 2011 (post-construction phase/ 337 survey days).

SPECIES	Number of Road Mortalities Pre-Construction	Number of Road Mortalities Post-Construction
Medium Sized Mammals		
Coyote	43	5
Striped Skunk	11	12
Raccoon	2	2
Opossum	2	4
Bobcat	0	1
Badger	0	1
Domestic Dog	1	1
Domestic Cat	3	2
Small Mammals		
Rabbit	47	136
Ground Squirrel	22	22
Wood Rat	5	11
Mouse	1	3
Gopher	2	2
Birds		
Barn Owl	16	5
Red-tailed Hawk	1	1
Unknown Bird	11	11
Crow	2	7
Raven	2	1
Roadrunner	1	0
Duck	1	3
Dove	19	10
House Finch	1	0
Seagull	1	3
Reptiles and Amphibians		
Misc. Snakes	11	13
Bull Frog	3	0
Western Toad	4	0
Lizard	0	1
Unknown Animal	10	8
Total # of Species	**222**	**265**

Table 2. Total number of coyotes killed each month by vehicles along SR 23 survey route January 7, 2004-October 30, 2006 (pre-construction phase).

MONTH	2004	2005	2006	Month Totals
January	2	1	0	3
February	2	2	1	5
March	3	1	1	5
April	3	1	1	5
May	3	2	1	6
June	2	0	3	5
July	0	1	1	2
August	1	1	0	2
September	2	1	0	3
October	3	0	2	5
November	0	1	X	1
December	1	0	X	1
Yearly Totals:	22	11	10	43

Table 3. Total number of species identified with remote cameras at 3 culverts under SR 23 survey route, November 4, 2004 – October 30, 2006 (pre-construction phase) and May 4, 2009 – August 12, 2011 (post-construction phase).

Species	Camera Number											
	1A		2A		3B		4B		5C		6C	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Coyote	1	63	18	38	342	484	588	378	7	30	-	93
Striped Skunk	-	6	4	17	74	629	173	1318	3	126	-	67
Raccoon	-	18	6	25	7	21	22	26	27	192	2	196
Bobcat	-	-	-	2	-	-	7	2	3	5	5	6
Badger	-	-	-	1	-	1	-	-	-	-	-	-
Opposum	-	28	2	18	-	1	1	66	-	2	-	-
Domestic Dog	-	5	-	-	-	1	-	5	-	-	-	-
Rabbit	-	70	48	214	-	43	3	138	8	32	-	40
Squirrel	-	9	7	61	2	1	4	152	1	11	-	13
Weasel	-	-	-	-	-	-	-	1	-	-	-	-
Wood Rat	-	13	-	-	-	5	-	-	2	34	-	16
Mouse	-	2	-	-	-	-	-	-	-	-	-	-
Duck	-	-	3	-	-	-	-	-	-	-	-	-
Bird	-	51	21	2	3	1	6	10	5	43	1	21
People	-	41	3	36	12	2	9	1	2	8	-	-
Trips	4	37	50	53	346	183	634	355	39	221	4	29
Days in Field	29	387	487	733	498	520	526	561	223	561	122	726
Total Number of Photos	5	344	162	467	786	1372	1447	2452	97	704	12	481
No. of Photos Taken/ Day/ Camera	0.17	0.89	0.33	0.64	1.58	2.64	2.75	4.37	0.43	1.25	0.10	0.66
No. of Photos Taken/Day/ Culvert	Culvert A Pre = 0.32 Post = 0.72				Culvert B Pre = 2.18 Post = 3.54				Culvert C Pre = 0.32 Post = 0.92			

Table 4. Total number of confirmed crossings by wildlife in 3 culverts under SR 23, November 4, 2004 – October 30, 2006 (pre-construction phase) and May 4, 2009 – August 12, 2011 (post-construction phase).

| Species | CULVERT | | | | | |
| | A | | B | | C | |
	Pre	Post	Pre	Post	Pre	Post
Coyote	-	6	39	183	-	6
Striped Skunk	-	-	4	65	-	48
Raccoon	-	3	-	3	-	6
Opossum	-	1	-	-	-	-
Total Detections (n)	0	10	43	251	0	60
Total Survey Days	30	387	509	520	124	561
Crossing rate (n/survey days)	**0**	**0.03**	**0.08**	**0.48**	**0**	**0.11**

Table 5. Total number of individuals for each species (excluding rabbits) detected by remote cameras inside the fence and walking through the one-way gate (IT), outside the fence and walking through the one-way gate (OT), inside the fence and walking by the one-way gate (IB), and outside the fence and walking by the one-way gate (OB) along SR 23 survey route, February 17, 2010 – August 12, 2011 (6 east gates monitored for 2440 survey days) and August 25, 2010 – August 12, 2011 (6 west gates monitored for 1718 survey days).

Species	IT	OT	IB	OB
Coyote	214	157	72	171
Striped Skunk	392	145	178	44
Raccoon	6	10	5	-
Bobcat	17	8	3	2
Badger	1	1	2	1
Opossum	45	15	10	3
Weasel	2	1	4	-
Domestic Dog	2	1	3	4
Domestic Cat	57	23	48	23
People	30	28	-	-
Total detections (n)	766	389	325	248
Detection rate (n/survey days)	**0.18**	**0.09**	**0.08**	**0.06**

Table 6. Total wildlife detections/day (excluding rabbits) going through (inside the fence and through = IT; outside the fence and through = OT) and walking by (inside the fence and walk by = IB; outside the fence and walk by = OB) the 6 one-way gates used by people (2054 survey days) and the 6 one-way gates not used by people (2104 survey days).

Detection Direction	Gates Used by People		Gates Not Used by People	
	Detection rate (*n*/survey days)	*n*	Detection rate (*n*/survey days)	*n*
IT	0.22	441	0.14	294
OT	0.12	236	0.06	125
IB	0.08	170	0.07	151
OB	0.10	203	0.02	46

Figure 1. Study area showing location of culverts and one-way gates.

Figure 2. Three culverts along SR 23 study area.

Culvert A

Culvert B

Culvert C

Figure 3. Chain-link wildlife exclusion fence buried 2 feet into the ground with a total height above ground of 6 or 8 feet.

Figure 4. One-way gate designed to allow animals that are trapped inside the right-of-way to safely exit.

Figure 5. Wire mesh secured on the one-way gate tines to prevent flexibility that may allow animals to bend the tines and squeeze through.

Figure 6. Gap between tine ends to allow flexing at the point an animal would pass through.

Figure 7. Digital remote camera secured in steel container used to monitor culvert use.

Figure 8. Digital remote camera used to monitor one-way gate use.

Figure 9. Locations of animals hit on the road during pre-construction monitoring, November 4, 2004 to October 30, 2006.
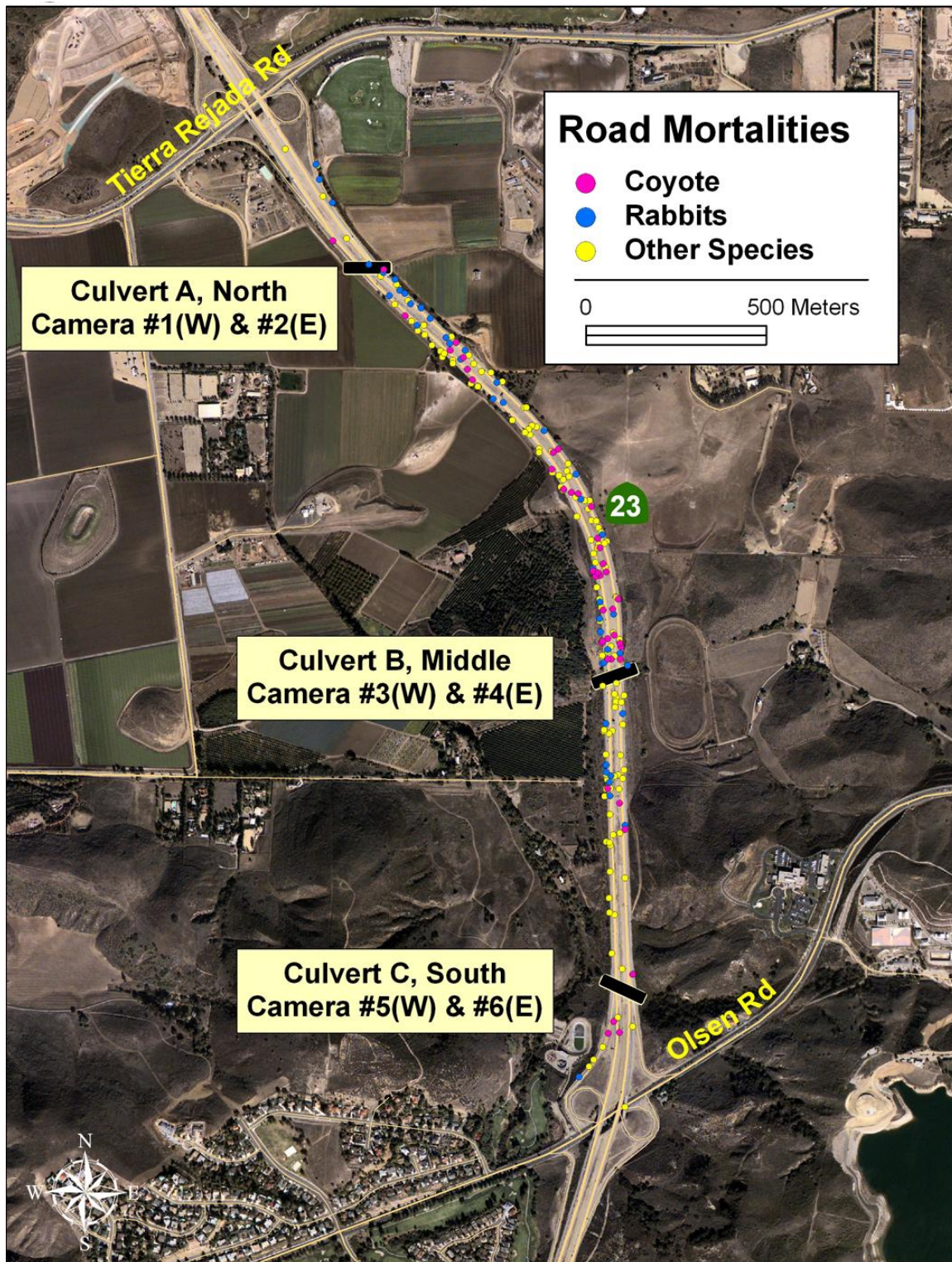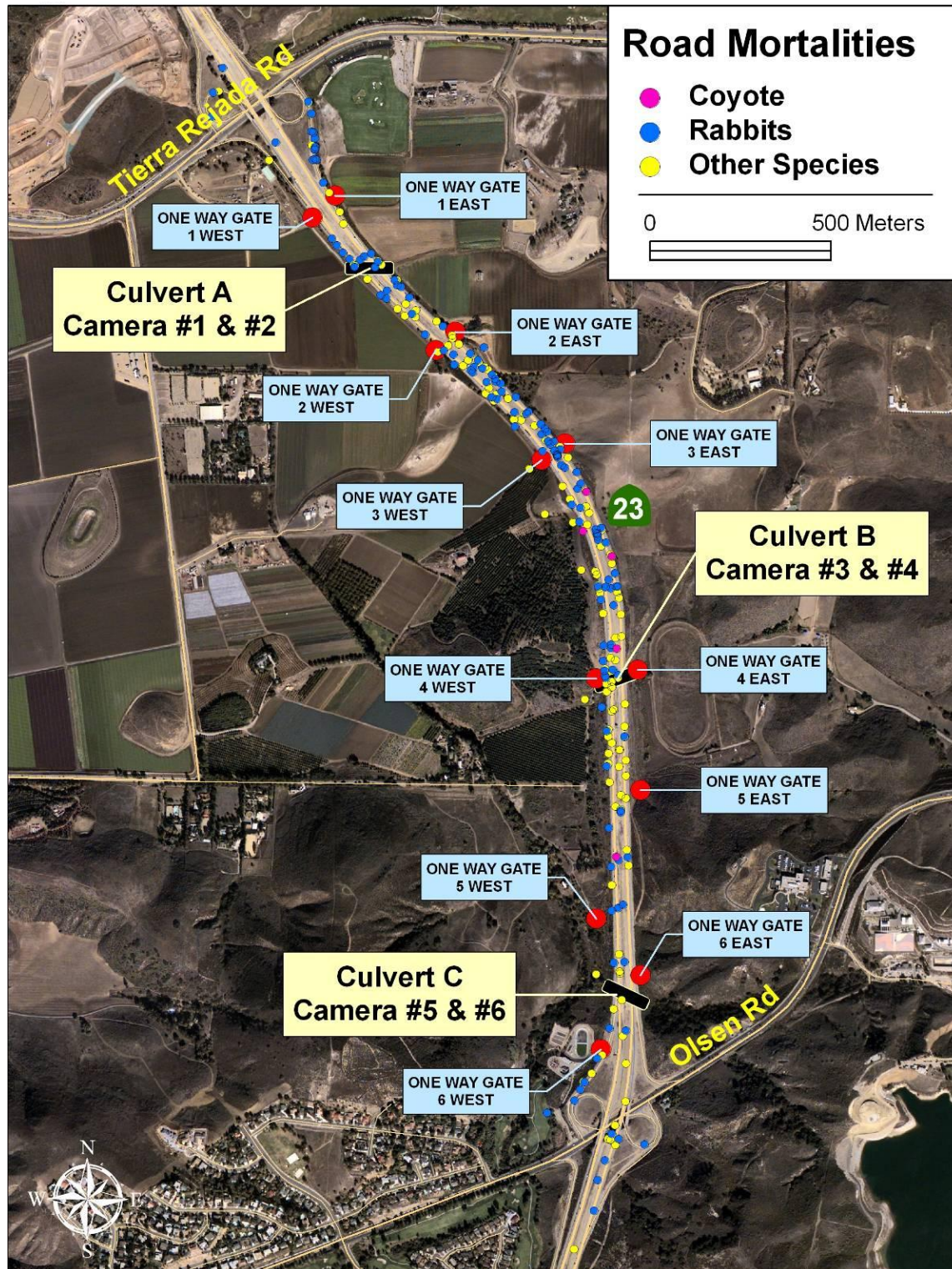
Figure 10. Coyote hit by vehicle along SR 23.

Figure 11. Locations of animals hit on the road during post-construction monitoring (May 4, 2009 to August 12, 2011) and locations of 12 one-way gates.

Figure 12. Culverts A and C before and after being cleared.

Culvert A **Culvert C**

BEFORE

AFTER

Figure 13. Coyote and Skunk in Culvert B

Figure 14. Remote camera picture showing bobcat jumping out of the western side of Culvert C before it was cleared.

Figure 15. Raccoons foraging in Culvert C.

Figure 16. People using one-way gates.

Figure 17. Animals passing through the one-way gates in both directions.

Series of 3 pictures showing coyote passing through the one-way gate the intended direction (from inside the fenced freeway to the outside).

Series of 3 pictures showing coyote passing through the one-way gate the wrong way (entering the freeway side of the fence).

Series of 3 pictures showing bobcat passing through the one-way gate the wrong way.

Series of 3 pictures showing raccoon passing through the one-way gate the wrong way.

Figure 18. Coyote approaching the one-way gate from outside the freeway, turning around and leaving.

Figure 19. Coyote biting on metal one-way gate tine from outside the freeway side of the fence.

Figure 20. Coyote with mange identified using 3 one-way gates on each side of the freeway in both directions.
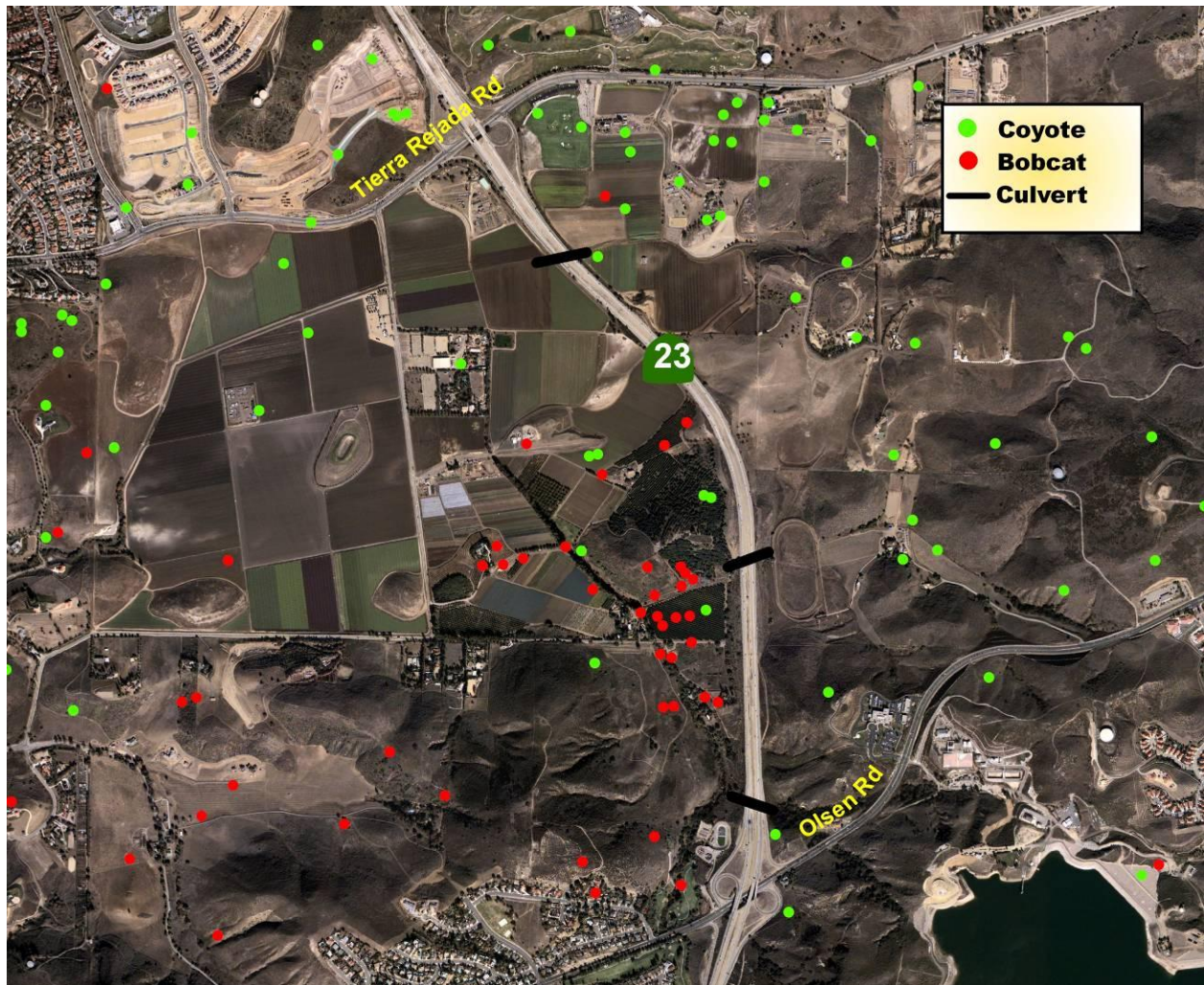

Figure 21. Long-tailed weasel, badger, and bobcat photographed using one-way gates.

Figure 22. Locations of 1 bobcat and 4 radio-collared coyotes studied by NPS from 1996-2003. All individuals were located on both sides of the freeway.
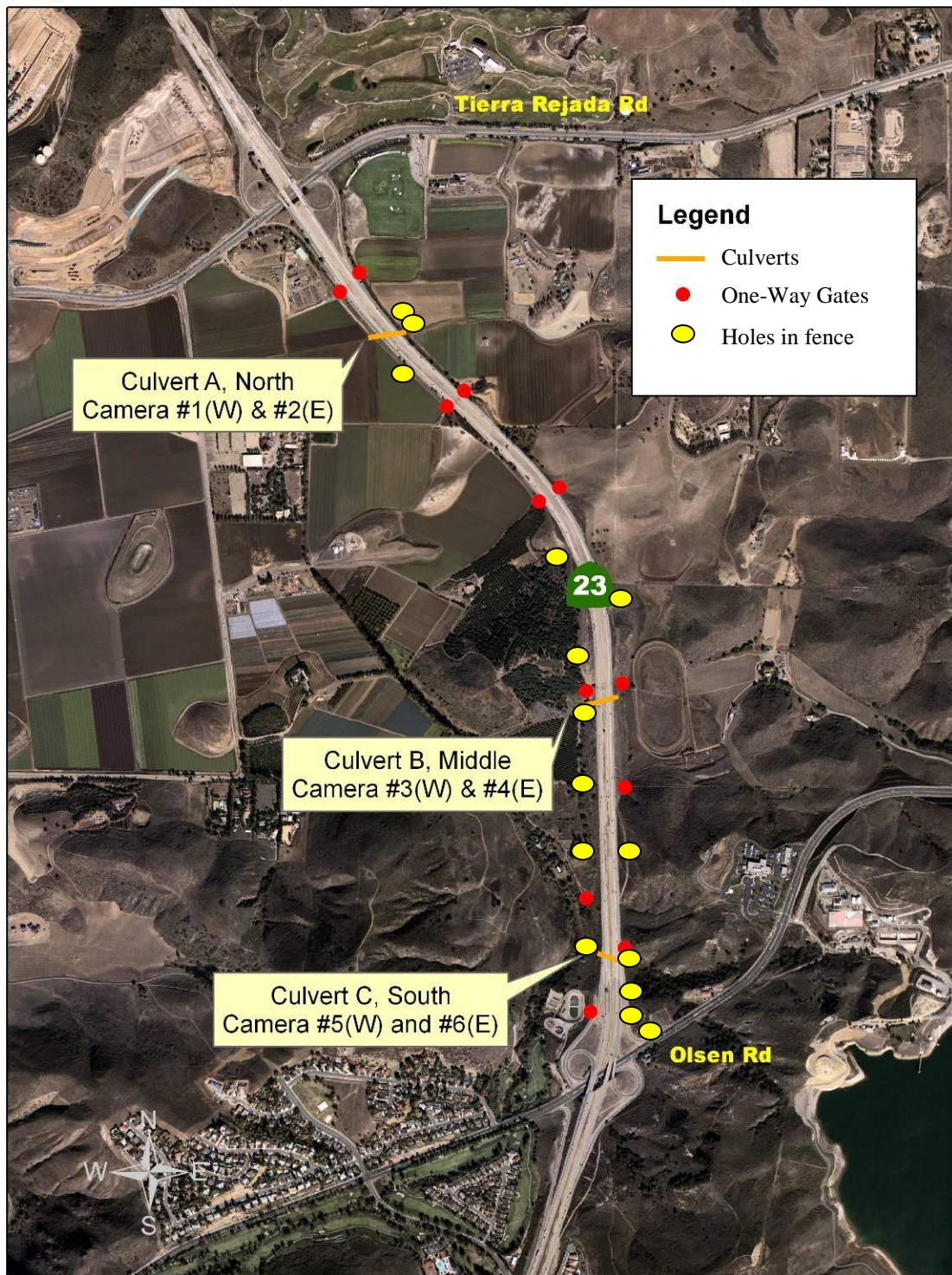
Figure 23. 23cm gap under the wildlife exclusion fence. Tracks of coyote and raccoon have been found at this location going under the fence and accessing the right-of-way.

Figure 24. Locations of 15 holes identified in March 2012 along the wildlife proof fence.

Figure 25. The wire mesh should extend out to the tine ends to improve the one-way gates so animals cannot pass through the wrong way.

Figure 26. Bobcat and coyote passing through the one-way gate between the tines.

Figure 27. Tines bent and broken off from people using the one-way gate.

Figure 28. Coyote and skunk passing through the one-way gate the intended way.

Figure 29. Spring-loaded swing gate in wildlife exclusion fence (Credit: Tony Clevenger).

Figure 30. Examples of escape ramp (jump-out) for wildlife trapped inside the fenced highway right-of-way (Credit: Tony Clevenger).

Figure 31. Small hinged door in wildlife exclusion fence for escape of medium-sized mammals (Credit: Tony Clevenger).

Figure 32. Example of pipes placed in culvert to provide cover for small mammal passage (Credit: Tony Clevenger).